IMPROVED TIME DOMAIN METHOD TO MEASURE NEAR-FIELD DISTRIBUTION OF BURIED-OBJECT

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Abstract

The paper analyses the ground antenna echo using microwave frequency detector and high speed sampling technology and a new method detecting buried objects in time domain near-field is presented. The method detecting particular reflection echo frequency of microwave pulse via digital signal processing is to reduce the false alarm rate. Simulation results show that this method has advantages of easy identification and high precision.

Key words: near-field measurement; mine detection; FDTD; microwave frequency detector; high-speed sampling

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I. INTRODUCTION

Recently, the accuracy of buried-objects detection system is increasing important which decided personal safety in mine affected areas. Few technology is employed in the real world to detect land mines because of high false alarm rate [1]. Since mine detection requires low false alarm rate, improving the precision of detection system should be studied. Many research works have been reported in the control of false alarm rate. Angular correlation function [2] and a statistical approach method [3] are employed to detect buried objects.

Traditional method of detecting buried objects is to analysis the reflection echo amplitude, which is a analog signal detecting method and difficult in identifying the existence of several reflection echo in the lossy medium. A novel digital method detecting predesignated reflection echo frequency is presented to detect buried objects.

II. THEORY AND MEASURE PRINCIPLE

With the development of finite time difference domain (FDTD) theory, it has been used to study time domain near-field measurement. FDTD as a numerical method to solve Maxwell's equations was introduced by Yee in 1966 [4], which divided both space and time into discrete grids. The electromagnetic parameters can be figured out in combination with the boundary conditions. The curl equations that are used in the FDTD algorithm are

$$\bigtriangledown \times \mathbf{E} = -\mu \frac{\partial \mathbf{H}}{\partial t} \qquad \bigtriangledown \times \mathbf{H} = \varepsilon \frac{\partial \mathbf{E}}{\partial t} + \sigma \mathbf{E} \tag{1}$$

where μ is permeability, ε is permittivity and σ is electric conductivity.

For a two dimensions free space time domain near-field measurements system, we assume that the dielectric media is nonmagnetic, *i.e.* $\mu = \mu_0$, the **H**-field and **E**-field can be written as [5,6]

$$H_x(i,j,t+1) = H_x(i,j,t) - \frac{dt}{\mu_0 dy}[E_z(i,j,t) - E_z(i,j-1,t)] \tag{2}$$

$$H_y(i,j,t+1) = H_y(i,j,t) - \frac{dt}{\mu_0 dx}[E_z(i,j,t) - E_z(i-1,j,t)] \tag{3}$$

$$E_z(i,j,t+1) = \frac{\varepsilon_\infty}{\varepsilon_\infty + \chi_0(i,j)} E_z(i,j,t) + \frac{1}{\varepsilon_\infty + \chi_0(i,j)} \sum_{m=0}^{t-1} E_z(i,j,t-m)\Delta\chi_m(i,j) + f(H_x,H_y) \tag{4}$$

and

$$
\begin{aligned}
f(H_x, H_y) \;=\; & \frac{dt}{[\varepsilon_\infty + \chi_0(i,j)]\varepsilon_0 dx}[H_y(i+1,j,t) - H_y(i,j,t)] \\
& - \frac{dt}{[\varepsilon_\infty + \chi_0(i,j)]\varepsilon_0 dy}[H_x(i,j+1,t) - H_x(i,j,t)]
\end{aligned} \tag{5}
$$

where ε_s is dielectric's static permittivity, ε_∞ is dielectric's optical permittivity, μ_0 is dielectric's permeability, t_0 is dielectric's relaxation time ,and

$$
\begin{pmatrix} \chi_0(i,j) \\ \Delta\chi_m(i,j) \end{pmatrix} = (\varepsilon_s - \varepsilon_\infty) \begin{pmatrix} 1 - exp(\frac{-dt}{t_0}) \\ exp(\frac{-mdt}{t_0})[1 - exp(\frac{-dt}{t_0})]^2 \end{pmatrix} \tag{6}
$$

is the susceptibility function.

A periodic microwave pulse has particular characters such as high peak value and low average value in near field, so it is difficult to detect the buried objects using amplitude detecting in the lossy medium. Therefor, to measure high peak value rapidly is the key point for mine detection system.

we use microwave frequency detector and high-speed sampling technology in receiver to realize the high efficiency detection. The component of detection system is shown in Figure 1.

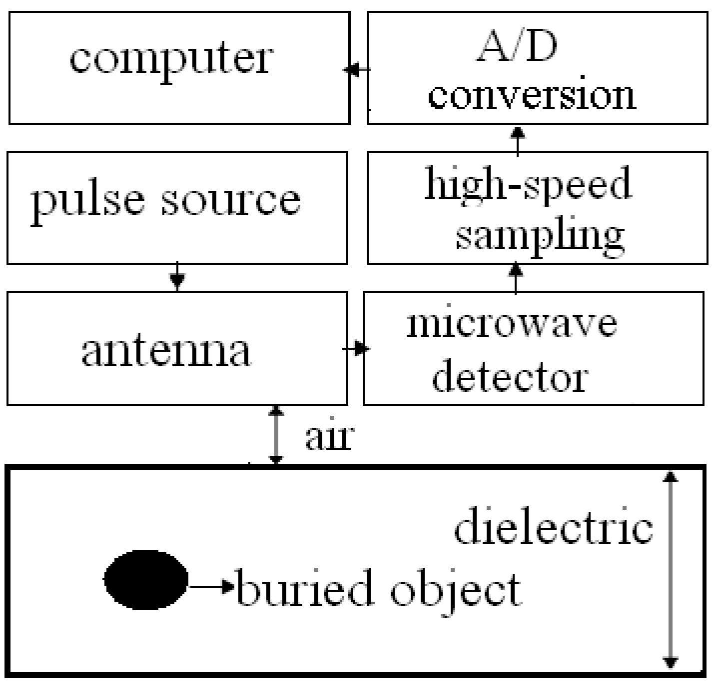

Figure 1: Schematic diagram of detection system

Microwave pulse was produced by microwave signal source and launched by transmitting antenna. The antenna can receive reflected pulse envelop at the same time.

Through microwave detector, we received time domain waveform of reflect pulse envelop. This effect is demonstrated in Figure 2. Δt is the microwave pulse width and T_0 is the period of microwave pulse.

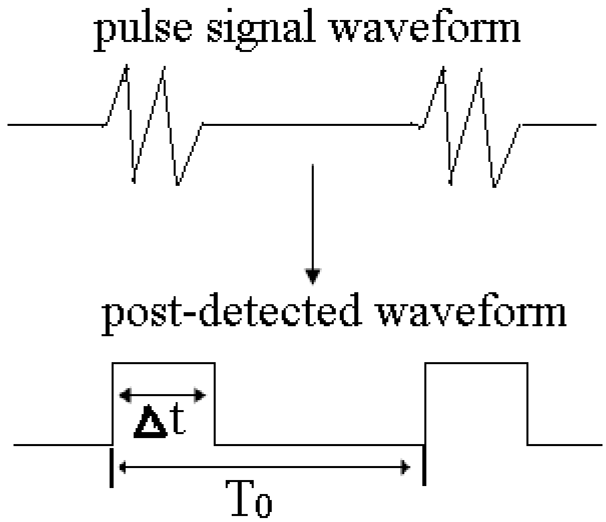

Figure 2: Schematic diagram of pulse signal detector

The high-speed sampling is key technology for pulse information during digital signal processing. High-speed **A/D** conversion circuit will records high level When the reflection echo of pulse is detected and records low level during other time.

Finally, completed digital form time domain waveforms can be shown in the computer.

III. SIMULATION AND RESULTS

An iron ball ($\varepsilon_r = 12$) with diameter is $15cm$ buried in a $120cm \times 120cm \times 45cm$ cubical vessel filled with dry sand ($\varepsilon_s = 2.5$). As is shown in the Figure 3. There are $15cm$ between air-dielectric interface with spherical center, $10cm$ between P_1 with air-dielectric interface, $10cm$ between P_1 with P_2 and $10cm$ between P_2 with P_3.

It is well known that FDTD utilizes the Yee cell for calculation at nodes of the finite-difference lattice. We set 420 grids in the X-direction and 100 grids in the Y-direction with a grid spacing $dx = dy = 0.5cm$ in the Yee cell.

We have chosen a microwave signal source with microwave pulse width Δt=1μs and pulse period $T_0 = 1ms$ as microwave pulse producer. A X-band microtrip antenna is employed to both transmit and receive microwave pulse. There is a microwave frequency detector to detect the $10GHz$ microwave at the receiving end. Then, we can transform analog signals

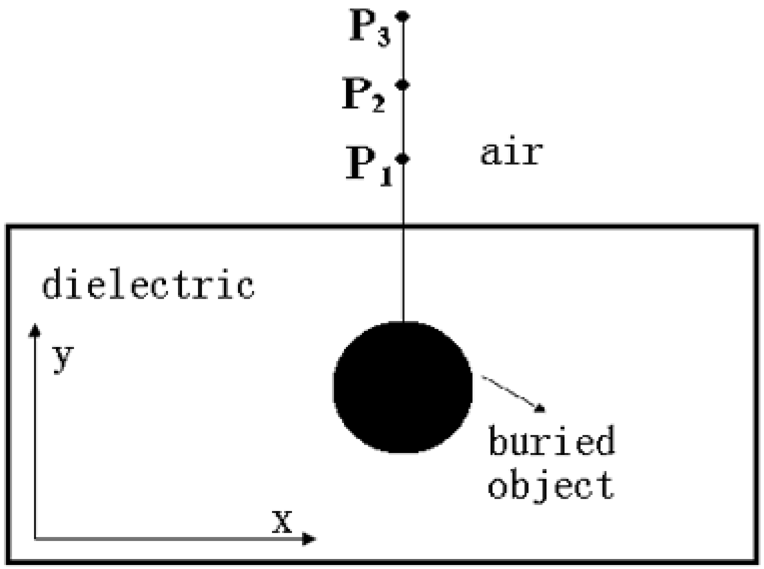

Figure 3: The near-field detecting configuration

into digital signals through high-speed sampling and **A/D** conversion. Finally, the completed time domain near-field information of refection echo is shown in the computer monitor.

We put the microtrip antenna at P_1, P_2 and P_3 to detect buried object respectively.

The analog signal simulation result is described in Figure 4 and digital signal simulation result in Figure 5.

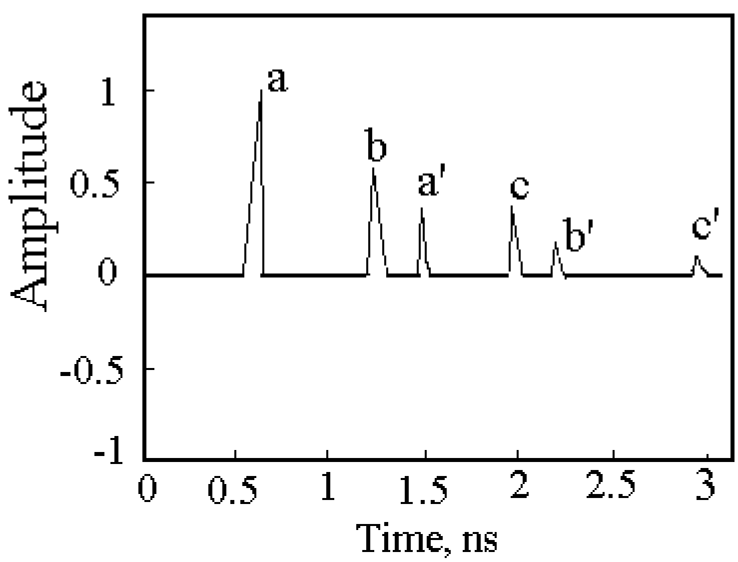

Figure 4: Analog signal simulation results

The peaks a and $a^{'}$ are the detecting results at P_1, b and $b^{'}$ are the detecting results at P_2 and c and $c^{'}$ are the detecting results at P_3.

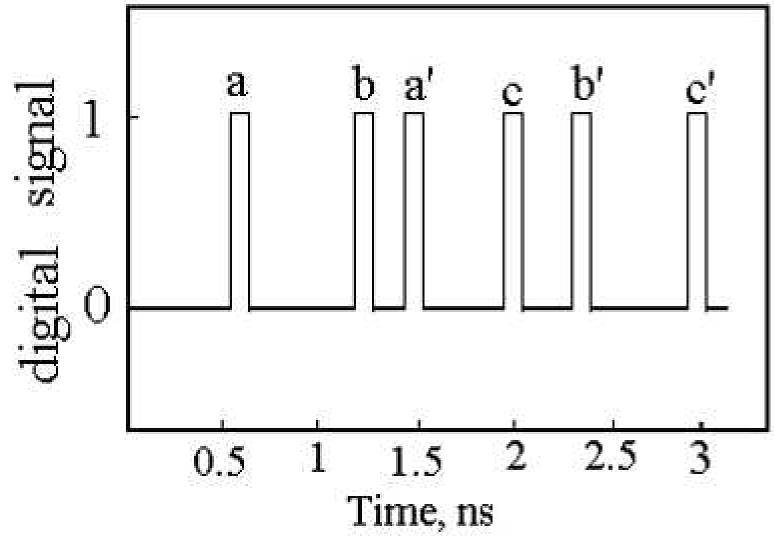

Figure 5: Digital signal simulation results

IV. CONCLUSION

The paper introduces a frequency detection method using microwave frequency detector and high-speed sampling technology to detect the buried-objects in time domain near-field. From the simulation results we can see that the method can get more clear and accurate reflection echo information from the buried-objects than traditional amplitude detecting method. At the same time, the low false alarm rate detecting method would be a new idea to detect remote objects.

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Figure Captions

Figure 1 Schematic diagram of detection system

Figure 2 Schematic diagram of pulse signal detector

Figure 3 The near-field detecting configuration

Figure 4 Analog signal simulation results

Figure 5 Digital signal simulation results